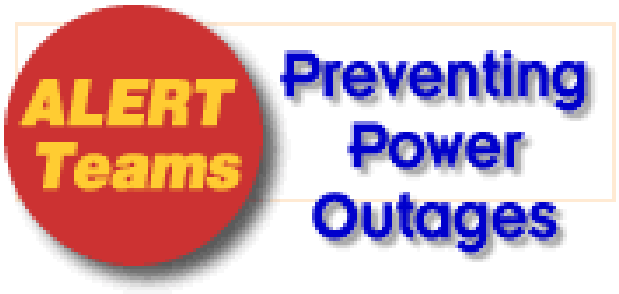
# ASSESSMENT OF LOAD AND ENERGY REDUCTION TECHNIQUES (ALERT)




This is Section 2c of the ALERT Book, which provides guidance for teams conducting energy use assessments at federal sites as part of the Assessment of Load and Energy Reduction Techniques (ALERT) Program.

The ALERT Book is published in five sections:

ALERT Book, Section 1. http://www.eren.doe.gov/femp/techassist/pdf/alertbook_1.pdf
ALERT Book, Section 2a. http://www.eren.doe.gov/femp/techassist/pdf/alertbook_2a.pdf
ALERT Book, Section 2b. http://www.eren.doe.gov/femp/techassist/pdf/alertbook_2b.pdf
ALERT Book, Section 2c. http://www.eren.doe.gov/femp/techassist/pdf/alertbook_2c.pdf
ALERT Book, Section 3. http://www.eren.doe.gov/femp/techassist/pdf/alertbook_3.pdf

## 6.2 Thermography △

### 6.2.1 Introduction

Infrared (IR) thermography can be defined as the process of generating visual images that represent variations in IR radiance of surfaces of objects. Similar to the way objects of different materials and colors absorb and reflect electromagnetic radiation in the visible light spectrum (0.4 to 0.7 microns), any object at temperatures greater than absolute zero emits IR energy (radiation) proportional to its existing temperature. The IR radiation spectrum is generally agreed to exist between 2.0 and 15 microns. By using an instrument that contains detectors sensitive to IR electromagnetic radiation, a two-dimensional visual image reflective of the IR radiance from the surface of an object can be generated. Even though the detectors and electronics are different, the process itself is similar to that a video camera uses to detect a scene reflecting electromagnetic energy in the visible light spectrum, interpreting that information, and displaying what it detects on a liquid crystal display (LCD) screen that can then be viewed by the device operator.

Because IR radiation falls outside that of visible light (the radiation spectrum to which our eyes are sensitive), it is invisible to the naked eye. An IR camera or similar device allows us to escape the visible light spectrum and view an object based on its temperature and its proportional emittance of IR radiation. How and why is this ability to detect and visualize an object's temperature profile important in maintaining systems or components? Like all predictive maintenance technologies, IR tries to detect the presences of conditions or stressors that act to decrease a component's useful or design life. Many of these conditions result in changes to a component's temperature. For example, a loose or corroded electrical connection results in abnormally elevated connection temperatures due to increased electrical resistance. Before the connection is hot enough to result in equipment failure or possible fire, the patterns are easily seen through an IR imaging camera, the condition identified and corrected. Rotating equipment problems will normally result in some form of frictional change that will be seen as an increase in the component's temperature. Faulty or complete loss of refractory material will be readily seen as a change in the components thermal profile. Loss of a roof's membrane integrity will

result in moisture that can be readily detected as differences in the roof thermal profile. These are just a few general examples of the hundreds of possible applications of this technology and how it might be used to detect problems that would otherwise go unnoticed until a component failed and resulted in excessive repair or downtime cost.

## 6.2.2 Types of Equipment

Many types of IR detection devices exist, varying in capability, design, and cost. In addition, simple temperature measurement devices that detect IR emissions but do not produce a visual image or IR profile are also manufactured. The following text and pictures provide an overview of each general instrument type.

**Spot Radiometer (Infrared Thermometer)** – Although not generally thought of in the world of thermography, IR thermometers use the same basic principles as higher end equipment to define an object's temperature based on IR emissions. These devices do not provide any image representative of an object's thermal profile, but rather a value representative of the temperature of the object or area of interest.

**Figure 6.2.1**. Typical IR spot thermometer

**Infrared Imager** – As indicated earlier, equipment capabilities, design, cost, and functionality vary greatly. Differences exist in IR detector material, operation, and design. At the

fundamental level, IR detection devices can be broken down into two main groups—imagers and cameras with radiometric capability. A simple IR imager has the ability to detect an object's IR emissions and translate this information into a visual image. It does not have the capability to analyze and quantify specific temperature values. This type of IR detection device can be of use when temperature values are unimportant and the object's temperature profile (represented by the image) is all that is needed to define a problem. An example of such an application would be in detecting missing or inadequate insulation in a structure's envelope. Such an application merely requires an image representative of the differences in the thermal profile due to absence of adequate insulation. Exact temperature values are unimportant.

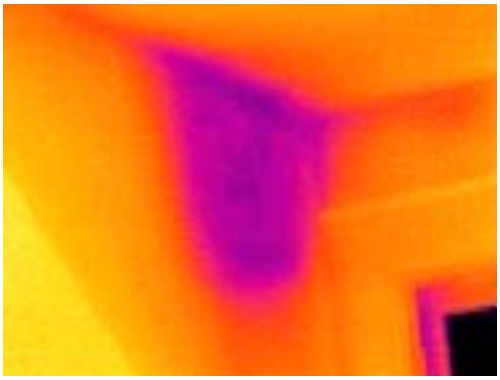


**Figure 6.2.2**. Internal house wall. Note dark area indicating cooler temperatures because of heat loss.

IR cameras with full radiometric capability detect the IR emissions from an object or camera field-of-view and translate this information into a visible format as in the case of an imager. In addition, these devices have the capability to analyze the image and provide temperature value for the area of interest. This capability is useful in applications where a temperature value is important in defining a problem or condition. For example, if an image indicated a difference between bearing housing temperature and the motor housing, it would be important in defining the problem to know the approximate temperature difference. This equipment and the supporting software can quantify temperatures anyplace within the IR image.

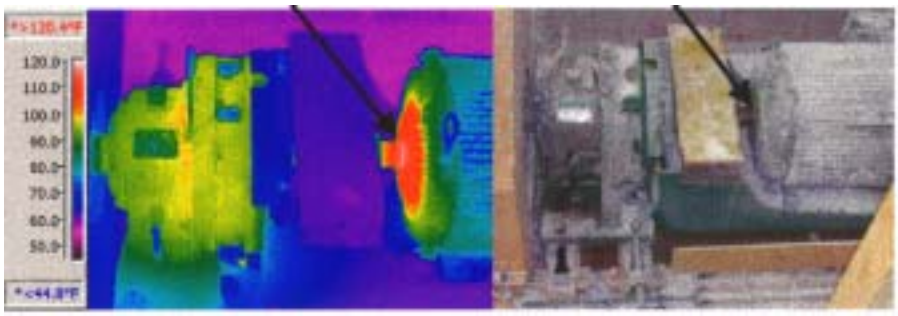


**Figure 6.2.3**. Hot motor bearing easily seen in IR image.
Note the light area indicating a hot bearing.

## 6.2.3 System Applications

### 6.2.3.1 Electrical System Applications

The primary value of thermographic inspections of electrical systems is locating problems so that they can be diagnosed and repaired. "How hot is it?" is usually of far less importance. Once the problem is located, thermography and other test methods, as well as experience and common sense, are used to diagnose the nature of the problem. The following list contains just a few of the possible electrical system-related survey applications:

- Transmission lines
  - Splices
  - Shoes/end bells
    - Inductive heating problems
  - Insulators
    - Cracked or damaged/tracking
- Distribution lines/systems
  - Splices
  - Line clamps
  - Disconnects
  - Oil switches/breakers
  - Capacitors
  - Pole-mounted transformers
  - Lightning arrestors
  - Imbalances
- Substations
  - Disconnects, cutouts, air switches
  - Oil-filled switches/breakers (external and internal faults)
  - Capacitors
  - Transformers
    - Internal problems
    - Bushings
    - Oil levels
    - Cooling tubes
    - Lightning arrestors
  - Bus connections

- Generator Facilities
  - Generator
    - Bearings
    - Brushes
    - Windings
    - Coolant/oil lines: blockage
  - Motors
    - Connections
    - Bearings
    - Winding/cooling patterns
    - Motor Control Center
    - Imbalances
- In-Plant Electrical Systems
  - Switchgear
  - Motor Control Center
  - Bus
  - Cable trays
  - Batteries and charging circuits
  - Power/Lighting distribution panels

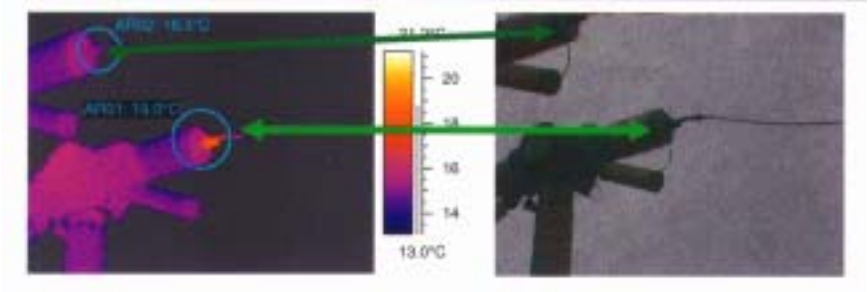



**Figure 6.2.4**. Air breaker problem. Note temperature difference between these air breaker contacts seen inside green circles.

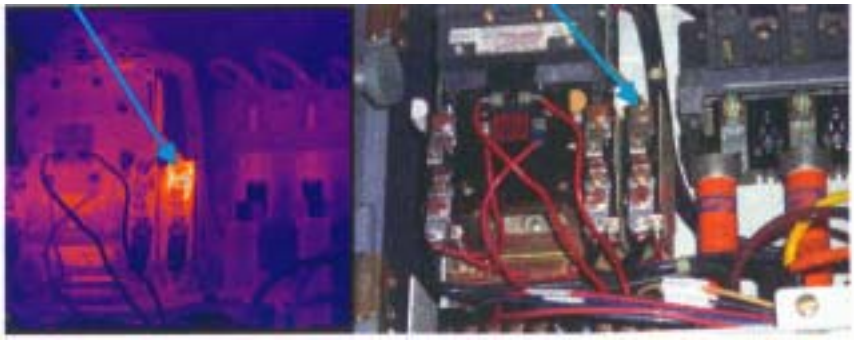


**Figure 6.2.5**. Overload connection problem. Note difference in IR image coloration between overload contacts.

### 6.2.3.2 Mechanical System Applications

Rotating equipment applications are only a small subset of the possible areas where thermography can be used in a mechanical predictive maintenance program. In addition to the ability to detect problems associated with bearing failure, alignment, balance, and looseness,

thermography can be used to define many temperature profiles indicative of equipment operational faults or failure. The following list provides a few application examples and is not all inclusive:

- Steam Systems
  - Boilers
    - Refractory
    - Tubes
  - Traps
  - Valves
  - Lines
- Heaters and furnaces
  - Refractory inspections
  - Tube restrictions
- Fluids
  - Vessel levels
  - Pipeline blockages
- Environmental
  - Water discharge patterns
  - Air discharge patterns
- Motors and rotating equipment
  - Bearings
    - Mechanical failure
    - Improper lubrication
  - Coupling and alignment problems
  - Electrical connections on motors
  - Air cooling of motors

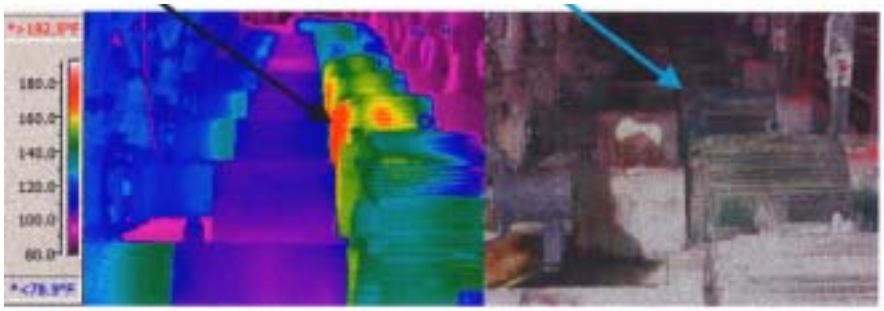


**Figure 6.2.6**. Warm inboard motor bearing. Image taken in a manner to readily compare IR images of several running motors.

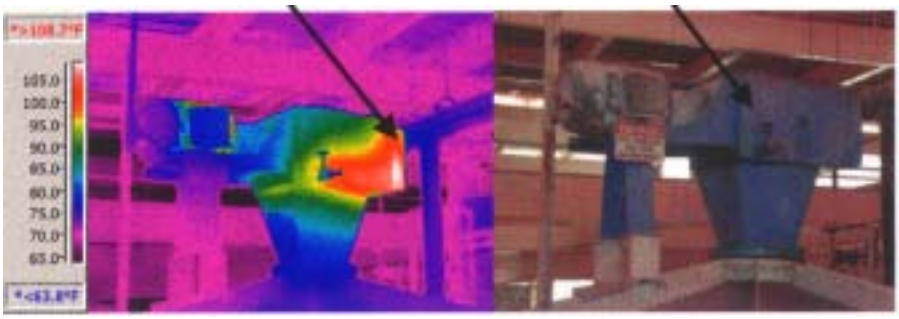



**Figure 6.2.7**. Possible gearbox problem indicated by white area defined by arrow. Design drawings of gearbox should be examined to define possible cause of elevated temperatures.

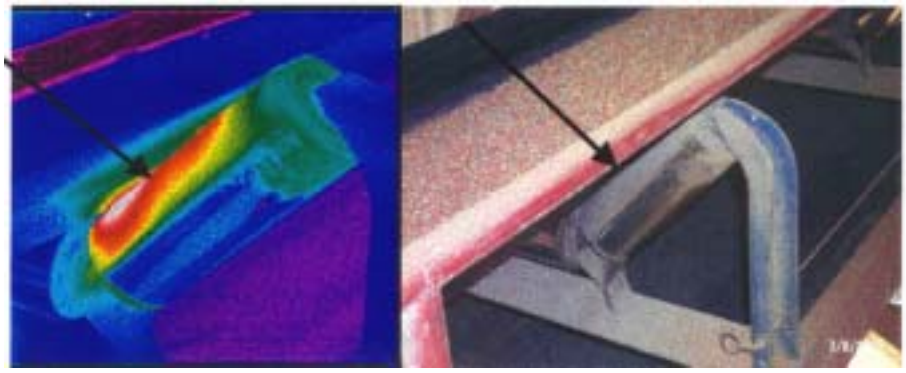


**Figure 6.2.8**. Seized conveyer belt roller as indicated by elevated temperatures in belt/roller contact area.

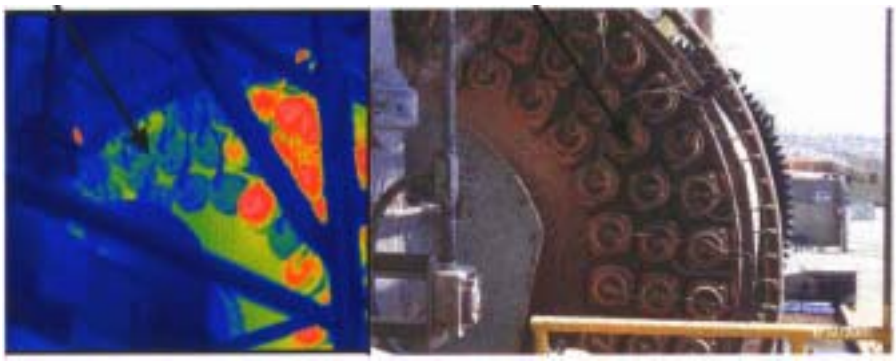


**Figure 6.2.9**. Inoperable steam heaters seen by cooler blue areas when compared to the operating heaters warmer red or orange colors.

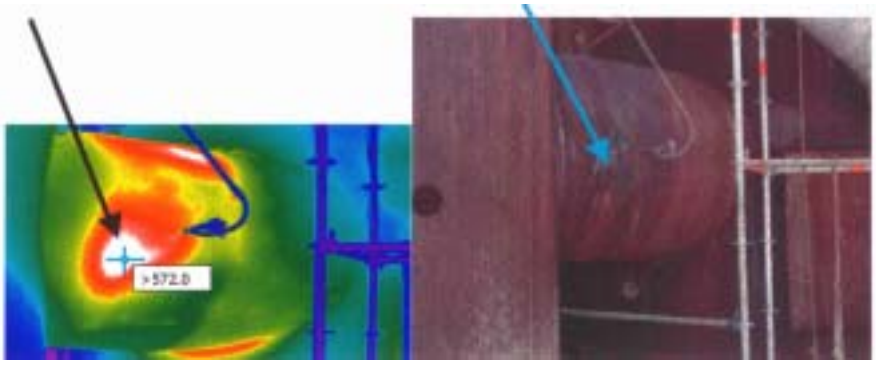
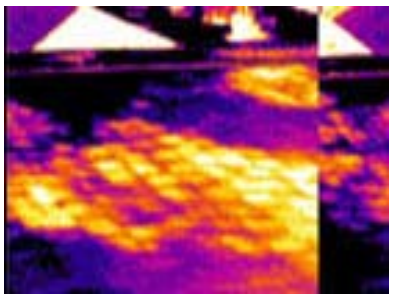
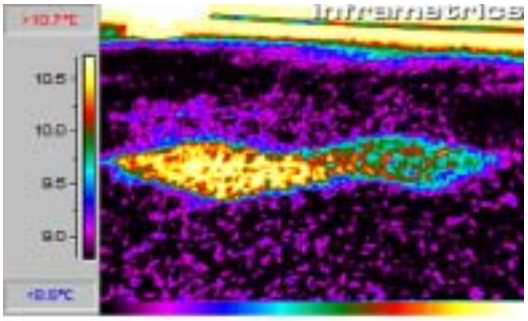


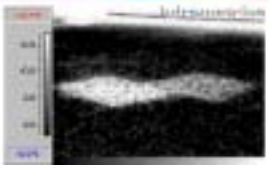
**Figure 6.2.10**. Refractory breakdown readily seen by white area in IR image.

### 6.2.3.3 Roof Thermography

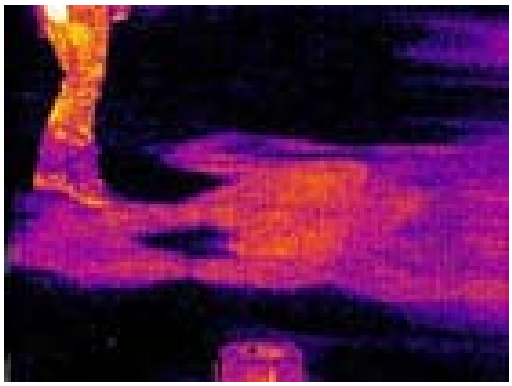
Out of sight, out of mind. This old adage is particularly true when it applies to flat roof maintenance. We generally forget about the roof until it leaks on our computers, switchgear, tables, etc. Roof replacement can be very expensive and at a standard industrial complex easily run into the hundreds of thousands of dollars. Depending on construction, length of time the roof has leaked, etc., actual building structural components can be damaged from inleakage and years







**These images show elevated temperatures of roof insulation due to difference in thermal capacitance of moisture-laden insulation.**



of neglect that drive up repair cost further. Utilization of thermography to detect loss of a flat roof's membrane integrity is an application that can provide substantial return by minimizing area of repair/replacement. Roof reconditioning cost can be expected to run less than half of new roof cost per square foot. Add to this the savings to be gained from reconditioning a small percentage of the total roof surface, instead of replacement of the total roof, and the savings can easily pay for roof surveys and occasional repair for the life of the building with change left over.

### 6.2.4 Equipment Cost/Payback

As indicated earlier, the cost of thermography equipment varies widely depending on the capabilities of the equipment. A simple spot radiometer can cost from $500 to $2500. An IR imager without radiometric capability can range from $12,000 to $20,000. A camera with full functionality can cost from $35,000 to $65,000. Besides the camera hardware, other program cost are involved. Computer hardware, personnel training, manpower, etc., needs to be accounted for in the budget. Below is a listing of equipment and program needs recommended by a company recognized as a leader in the world of IR program development:

- Level I thermographic training
- Level II thermographic training
- Ongoing professional development
- IR camera with wide-angle, normal, and telephoto lenses
- Report software
- Laptop computer
- Color printer
- Digital visual camera
- Personal Protective Equipment (PPE) for arc flash protection
- $80,000 IR camera and accessories
- $8,000 Level I and II training
- $45,000 - estimated annual loaded thermographer cost

Payback can vary widely depending on the type of facility and use of the equipment. A production facility whose downtime equates to several thousands of dollars per hour can realize savings much faster than a small facility with minimal roof area, electrical distribution network, etc. On the average, a facility can expect a payback in 12 months or less. A small facility may consider using the services of an IR survey contractor. Such services are widely available and costs range from $600 to $1,200 per day. Contracted services are generally the most cost-effective approach for smaller, less maintenance-intensive facilities.

### 6.2.5 Case Studies

**IR Diagnostics of Pump**

A facility was having continual problems with some to its motor and pump combinations. Pump bearings repeatedly failed. An IR inspection confirmed that the lower thrust bearing was warmer than the other bearing in the pump. Further investigation revealed that the motor-pump combination was designed to operate in the horizontal position. In order to save floor space, the pump was mounted vertically below the motor. As a result, the lower thrust bearing was overloaded leading to premature failure. The failures resulted in a $15,000 repair cost, not including lost production time ($30,000 per minute production loss and in excess of $600 per minute labor).

**IR Diagnostics of Steam Traps**

Steam trap failure detection can be difficult by other forms of detection in many hard to reach and inconvenient places. Without a good trap maintenance program, it can be expected that 15% to 60% of a facility's traps will be failed open. At $3/1,000 lb (very conservative), a 1/4-in. orifice trap failed open will cost approximately $7,800 per year. If the system had 100 traps and 20% were failed, the loss would be in excess of $156,000. An oil refinery identified 14% of its traps were malfunctioning and realized a savings of $600,000 a year after repair.

**IR Diagnostics of Roof**

A state agency in the northeast operated a facility with a 360,000 square foot roof area. The roof was over 22 years old and experiencing several leaks. Cost estimates to replace the roof ranged between $2.5 and $3 million. An initial IR inspection identified 1,208 square feet of roof requiring replacement at a total cost of $20,705. The following year another IR inspection was performed that found 1,399 square feet of roof requiring replacement at a cost of $18,217. A roof IR inspection program was started and the roof surveyed each year. The survey resulted in less than 200 square feet of roof identified needing replacement in any one of the following 4 years (one year results were as low as 30 square feet). The total cost for roof repair and upkeep for the 6 years was less than $60,000. If the facility would have been privately owned, interest on the initial $3 million at 10% would have amounted to $300,000 for the first year alone. Discounting interest on $3 million over the 5-year period, simple savings resulting from survey and repair versus initial replacement cost ($3 million - $60,000) amount to $2,940,000. This figure does not take into account interest on the $3 million, which would result in savings in excess of another $500,000 to $800,000, depending on loan interest paid.

## 6.2.6 Equipment Resources

**FLIR Systems**, Boston
16 Esquire Road
North Billerica, MA 01862
Telephone: (978) 901-8000

**Mikron Instrument Company, Inc.**
16 Thornton Road
Oakland, NJ 07436
Telephone: (805) 964-9797

**Indigo Systems Corporation**
5385 Hollister Avenue #103
Santa Barbara, CA 93111
Telephone: (805) 964-9797
Fax: (805) 964-7708

**Raytheon Infrared**
Customer Service
Telephone: (800) 990-3275 (International)
Telephone: (972) 344-4000 (U.S. only)
Email: infrared@raytheon.com

**Nikon, Inc.**
1300 Walt Whitman Road
Melville, NY 11747-3064
Telephone: (631) 547-4200,
1-800-52-Nikon, or (516) 547-4355 (Electronic)

## 6.2.7 Infrared Service Companies

**Cooper Electric**
3883 Virginia Avenue
Cincinnati, OH 46227
Telephone: (613) 271-6000
Fax: (613) 627-3246

**Fox Systems, Inc.**
1771 US Hwy 41 SW
P.O. Box 1777
Calhoun, GA 30703

**Hartford Steam Boiler**
Engineering Services
Telephone: (800) 231-0907, ext. 1120
Email: Sandy_Sanor@hsb.com

**Infrared Services, Inc.**
P.O. Box 701
Littleton, CO 80160-0701
Voice: (303) 734-1746
Fax: (303) 734-1201

**Thermal Vision**
14 Grissom Place
Pueblo, CO 81001
Telephone: (719) 646-4073
Email: fps@rmi.net

## 6.2.8 Infrared Internet Resource Sites

**Academy of Infrared Thermography (www.infraredtraining.net)**

- Level I, II, and III certification information and training schedule.
- Online store (books, software, videos).
- Online resources (links, image gallery, message board).

- Install ceiling and wall insulation.
- Insulate water heaters and supply pipes.

## Refrigeration

- Perform scheduled maintenance on units.
- Keep evaporator coils clean and free of ice build-up
- Adjust door latches and replace worn door gaskets.
- Use night covers on display cases.
- Disconnect anti-condensate heaters.
- Keep refrigerators full (water jugs make good fillers).
- Install auto door-closers and strip curtains on walk-in freezers or coolers.

## Food service equipment

- Consider replacing some or all electric cooking equipment with comparably sized gas-fired equipment.
- Purchase insulated cooking equipment whenever possible (e.g., fryers, ovens, coffee machines). Insulation maintains more heat in the equipment and transmits less to the environment.
- Preheat cooking equipment no longer and at no higher setting than the manufacturer's recommendation.
- Use cooking equipment to capacity. Fully loaded equipment utilizes energy more efficiently.
- Turn off backup fryers during low production periods.
- Filter fryer oil at least once a day to extend the oil life.
- Don't overload fryer baskets beyond the recommended capacity. Overloading increases cook time.
- Where applicable, replace broilers with grooved or smooth griddles to significantly reduce the associated energy consumption.
- Turn ovens down or off during low production periods.
- Make sure oven doors fit tightly and gaskets are in good condition.

- Communication (classifieds, news, industry related information.
- Company profile and contact information.

**Snell Infrared (Snellinfrared.com)**

- Training and course information.
- Industry links.
- IR library.
- Newsletter.
- Classifieds.
- IR application information.

**FLIR Systems (www.flir.com)**

- Product information.
- Image gallery.
- Application overview with images.
- Used camera source.

# Energy Tips

**Energy Tips is a Web-based fact sheet that provides energy costs for operating equipment.**

# Spot the Big Spenders

**Spot the Big Spenders is a Web-based fact sheet that provides energy costs for operating equipment.**

# Sample Instruments



- **Infrared (IR) Gun**
  - surface temperature measurement
- **Watt Meter**
  - simple power demand and consumption measurement
- **Ballast Detector**
  - magnetic or electronic
- **Light Meter**
  - light level readings
- **Window Coating Detector**
  - indicates low-e coating on which surface

Pacific Northwest Programs for Energy Efficiency, Demand Response, and Distributed Generation

| Measure Type | Bonneville Power Administration | | | | | Seattle City Light | PacifiCorp | | | Portland General | | | Puget Sound Energy | Avista Utilities | Idaho Power | Oregon Office of Energy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conservation and Renewables Discount (C&RD) Program | Conservation as Part of Augmentation (ConAug) | | | *Demand Exchange* | Energy Smart Services | Energy FinAnswer | Retrofit Incentive | *Energy Exchange* | Rebates and Incentives | *Demand Buy Back* | *Dispatchable Standby Generation* | *Voluntary Load Curtailment Service* | Energy Efficiency Incentives | *Energy Buy Back* | Energy Loan Program |
| | | Off-the-Shelf (LSO) | Custom (IRLC) | QuickStart | | | | | | | | | | | | |
| 1) O&M activities (includes reset building controls, retune HVAC controls, repair or replace economizers, dampers, and controls) | X | | X | X | | | | | | X | | | | | | |
| 2) Turn off equipment after office hours | | | | | | | | | | | | | | | | |
| 3) Turn off equipment during peak (curtailment or shift operating hours) | | | | | X | | | | X | | X | | X | | X | |
| 4) Lighting efficiency upgrades | X | X | X | X | | X | X | X | | X | | | | X | | X |
| 5) Replace and Improve HVAC, Motor Equipment or Controls Efficiency | X | | X | X | | X | X | X | | X | | | | X | | X |
| 6) Lower temperature of hot water tanks - electric & gas | | | | | | | | | | | | | | | | |
| 7) Build thermal storage to cool during peak | X | | | | | | | | | | | | | | | |
| 8) Build new electricity generation (diesel, gas, solar, wind) for peak reduction | X | | | | X | | | | | | | X | ? | | ? | X |
| 9) Same as #8 but use generator for "all day". | X | | | X | | | | | | | | | | | | X |
| 10) Measure & Diagnose Performance (meters) | X | | | | | | | | | X | | | | | | |
| 11) Run back-up generation to reduce peak demand | | | | | X | | | | | | | X | ? | | ? | |

Energy Efficiency Programs = Regular
Demand Response and Distributed Generation Programs = *Italics*

**NOTES**

Energy Efficiency, Demand Response, and Distributed Generation Programs Chart & Selections, courtesy of C. Goldman, Lawrence Berkeley National Laboratory

Bonneville Power Administration (BPA)
a) To participate in ConAug, customers must be served by a utility receiving 100% service from BPA.
b) To participate in Demand Exchange, participants must be able to shed at least 1 MW, although multiple facilities may be aggegated to meet this requirement.

PacifiCorp Programs
c) A 25% bonus for PacifiCorps Energy FinAnswer and Retrofit Incentives is available for projects installed prior to December 31, 2001.
d) To qualify for Energy FinAnswer, commercial retrofit projects must be at least 20,000 square feet. Smaller projects may be eligible for the Retrofit Incentive program. Additionally, projects must achieve at least 50% of savings from non-lighting measures and must have a simple payback of greater than one year.
e) Energy Exchange is available to customers with loads greater than 1 MW.

Portland General
f) To qualify for lighting rebates, the measure must result in at least 35% savings over the existing system. For large buildings (>20,000 sq. ft.), projects must have a simple payback of greater than two years, although some exceptions may be granted.
g) For the Dispatchable Standby Generator program, participants are compensated for the O&M and fuel costs, and may also be provided with upgraded control and communications hardware, in exchange for allowing PGE to remotely dispatch the unit.

Puget Sound Energy
h) To participate in the Voluntary Load Curtailment Program, customers must be able to reduce load by at least 500 kW during a minimum one-hour period.

Idaho Power
i) Participation in Energy Buy Back program limited to customers who can curtail at least 1 MW.
j) Current program expires March 14, 2002; unclear if program will be extended.

Oregon Office of Energy
k) Eligible new generation projects include only those that use renewable fuels, including water, wind, geothermal, solar, biomass, waste materials, and waste heat